

CONTRIBUTIONS TO THE MINERALOGY OF NORWAY

No. 35. The first occurrences of the rare mineral barylite, $\text{Be}_2\text{BaSi}_2\text{O}_7$, in Norway

By

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Abstract. Barylite was first found in some nepheline-syenite pegmatites in a nepheline syenite dike in the Lågen Valley, near the famous Langesundfjord district, within the Igneous Rock Complex of the Oslo Region. Subsequently, barylite was found in one old sample from one of the nepheline-syenite pegmatites in the Langesundfjord area. The paragenesis of the barylites is treated in some detail. The results of optical and spectrochemical determinations are given.

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Introduction

E. R. YGBERG (1941) gave a short summary of the history of the mineral barylite. It was first found in 1874 by BLOMSTRAND (1876) in the Långban Mine, Wärmaland, Sweden. Blomstrand regarded barylite as a Ba-Al-silicate. WEIBULL (1900) gave the first crystallographic and optical data of the mineral. AMINOFF (1923) restudied barylite and an analysis made by Almström disclosed that barylite was a Ba-Be-silicate. Aminoff gave the correct formula, $\text{Be}_2\text{BaSi}_2\text{O}_7$ and some new optical and crystallographic results. The second occurrence of barylite was reported by PALACHE and BAUER (1930) from Franklin, N.J., USA. They also reported some new physical and optical data on barylite. The third occurrence of barylite was found by Zhabin and Dykov at the Visjnjevye Gory (Cherry Mountains) in Ural, USSR, in 1958. The find was reported by ZHABIN and KAZAKOVA (1960). The fourth locality for barylite is the Seal Lake District, Labrador, Canada. The find was reported by HEINRICH and DEANE (1962). Additional data were given by NICKEL and CHARETTE (1962). The next find of the mineral was made by the present author in the Lågen (earlier Lougen) Valley 25 km NE of the Langesundfjord district in 1962. In 1964 barylite was found in one very old specimen from one of the nepheline-syenite pegmatites in the Langesundfjord area. The exact locality is not known, but the mineral association indicates that it belongs to the eudidymite locality on the small island Övre Arö in Langesundfjord.

The Lågen Valley locality

Nepheline-syenite pegmatites were encountered in nepheline-bearing rocks during the rebuilding of Highway 275 (now Highway 8) between Larvik and Kongsberg, in 1962. Near Larvik, c. 10 km north of Bommestad Bridge, just south of the farm Bratthagen in the Lågen Valley, a large road-cut was blasted through a trachytoid nepheline-syenite dike, in which were several cross-cutting nepheline-syenite pegmatites, up to 30 cm thick. This nepheline syenite had been analyzed and described as the Bratthagen foyaite dike by BRÖGGER (1897). OFTEDAHL (1960) dropped the name foyaite and just called

it a nepheline syenite. The chemical composition of the rock is that of a normal nepheline syenite. It consists of large (up to 20 mm long and 2–3 mm thick) tablets of microperthite, nepheline, some scattered grains of sodalite, lepidomelane, and a diopsidic pyroxene, rich in the aegirite molecule, as well as accessory titanite, magnetite, apatite, and very little zircon. The location of the road-cut with the exposed nepheline-syenite pegmatites is shown on the key-map (Fig. 1).

The nepheline-syenite pegmatites

The pegmatites are in general 10–30 cm thick, often rather irregularly cross-cutting, more or less continuous, dikes or veins. They are always controlled by tectonic features in the nepheline syenite dike. It is possible to group them into two types.

Type 1. The dikes of this type are controlled by typical, so-called 'flat-lying joints' in the sense of BALK (1937). The pegmatite fluid or magma was injected into these joints and began to crystallize. During the first time of consolidation, several movements took place. This is obvious, because the aegirite, ramsayite, and some of the catapleiite crystals are broken and bent. At the time of the crystallization of the feldspars and nepheline, these movements ceased and the joints were healed.

Later on new movements opened these zones again and very often split the brittle pegmatites into two parts along a plane parallel to the borders of the dikes. The central parts of these dikes then often became heavily zeolitized and altered. The contacts of this type of dike are always sharp against the host rock.

Type 2. These dikes are always confined to irregular, more or less steep-dipping fractures. Very often, angular fragments of the host rock completely surrounded by pegmatite material are observed. The dikes are not affected by later movements. The contacts are rather sharp, and these dikes are only slightly affected by zeolitization and alterations. Both types of dike may carry numerous druses, rather richly mineralized.

The nepheline-syenite pegmatites of the Lågen Valley are closely related to the dikes of the Langesundfjord area, although some minor mineralogical and geochemical differences seem to exist.

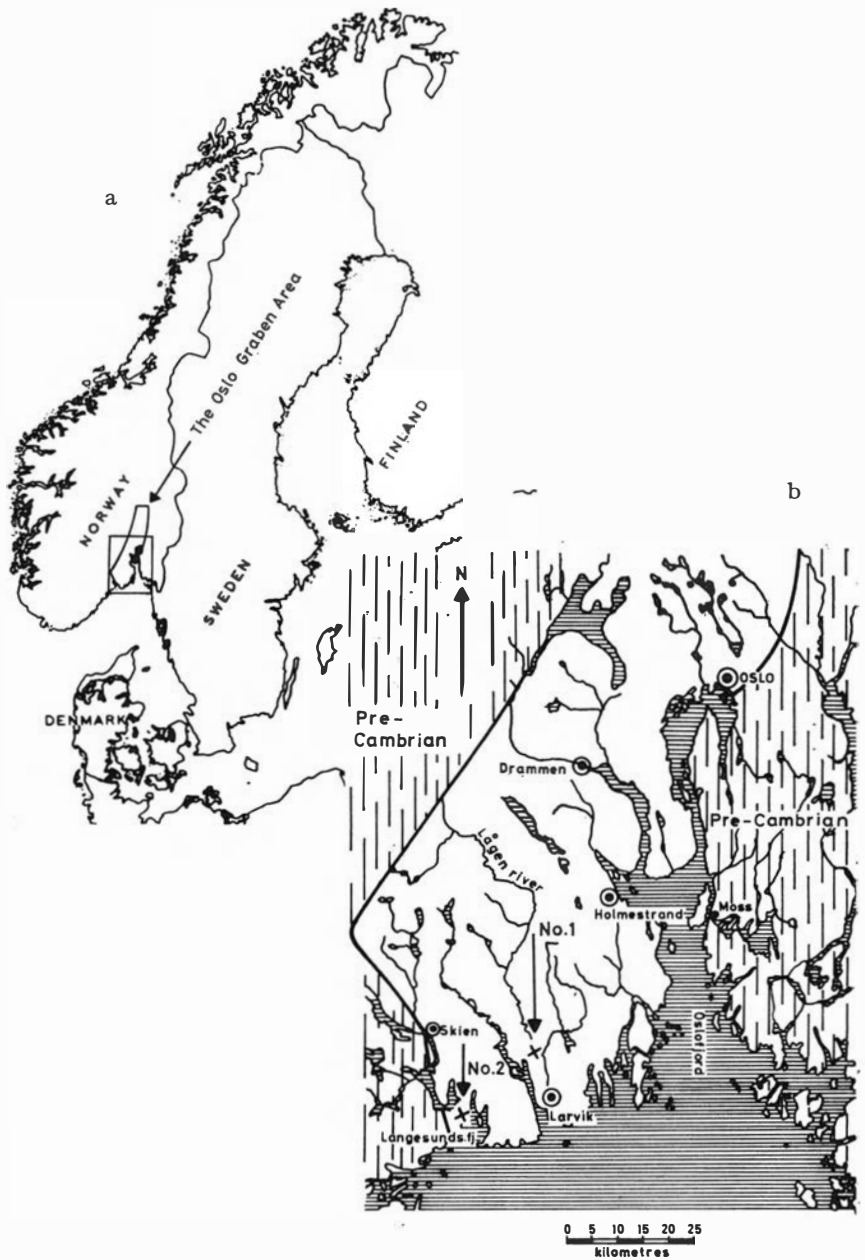


Fig. 1a. Key-map showing the location of the Oslo Graben Area.

Fig. 1b. Map of the southern part of the Oslo Graben Area. The barylite localities are marked by crosses and arrows.

No. 1. Lågen Valley.

No. 2. Upper Arö Island in the Langesundfjord Area.

The material

Most of the mineralized pegmatite material was lost because the nepheline syenite was used as road-metal. Some specimens were collected at the road-cut, but most of the material was found along the road several km south of the locality. Barylite was found in one sample only, coming from a 30 cm broad pegmatite dike, the core of which had been heavily zeolitized. Analcite, with aegirite and catapleiite, are the most important minerals. The specimen is strongly related to the genthelvite specimens. The genthelvite was examined by OFTEDAHL and SÆBÖ (1963). A short comment on the mineral association including the barylite was also given. The examinations showed that this genthelvite is by far the most pure Zn-member of the helvite group hitherto found.

The barylite material from the Lågen Valley will be kept at the Mineralogical-Geological Museum of the University of Oslo.

Identification

The mineral was identified by means of optical measurements. The X-ray powder pattern of the mineral is identical to that of barylite from Långban, Sweden, published by NEUMANN, SVERDRUP and SÆBÖ (1957). Spectrochemical determinations done by I. Oftedal proved the presence of the elements characteristic of barylite.

The old material from the Langesundfjord Area

The sample comes from one of the nepheline-syenite pegmatites in the Langesundfjord area. The label states only 'Analcim, Brevig'. It consists of an aggregate of analcite, with small amounts of helvite, zircon, aegirite, pulverulent bastnäsite pseudomorphs after ancylite, 'weißeyte' as shown by SÆBÖ (1963), natrolite, muscovite, pyrophanite, and barylite. The helvite has been treated earlier by OFTEDAL and SÆBÖ (1963). At the time of the examinations of the helvite, one of the authors (Sæbö) tentatively identified eudidymite. This supposed eudidymite was later, in 1964, identified as barylite. This mineral differs considerably from all other barylites hitherto described.

The crystals are extremely small and thin, short needles or threads lumped together and resembling cotton wool. The mineral occurs in small angular cavities in analcite. It is quite clear that it is pseudomorphous after another Be-mineral, probably meliphanite or leucophanite. The crystals are too small to allow exact optical measurements. The X-ray powder pattern matches exactly that of the barylite from the Lågen Valley. Spectro-chemical determinations done by I. Oftedal showed the presence of Ba, Be, and Si.

The sparseness of the material limits further examinations. The importance of the find is that it adds yet another species to the long list of minerals from the Langesund area.

The crystallographic setting, unit cell, and space group of barylite

The first crystallographic measurements were done by WEIBULL (1900), who concluded that the mineral was rhombic. A new setting was given by AMINOFF (1923) with the axial ratios $a : b : c = 0.8025 : 1 : 0.8376$. Aminoff confirmed that the mineral crystallizes in the rhombic system. YGBERG (1941) determined the unit cell of the Långban material and gave the setting of barylite. Later, SMITH (1956), who studied the Franklin material, confirmed the unit cell determinations of Ygberg, who also carried out the first structural work on barylite. Smith further published indexed powder d-values of barylite from Franklin, N.J. ZHABIN and KAZAKOVA (1960) published d-values for the barylite from the Urals, together with d-values for the Långban mineral, calculated from the $\sin^2 \theta$ -values published by Ygberg. Recently, HEINRICH and DEANE (1962) also published d-values for both the Långban and Seal Lake barylites.

The orientation of Ygberg and Smith is now generally accepted. It is used throughout this work. All data given by the earlier workers on barylite have been transformed into the orientation of Ygberg and Smith. The relation between the orientation of Ygberg and Smith and of Aminoff is $a_0 = c$, $b_0 = b$, $c_0 = 1/2a$. The transformation matrix from Aminoff to Ygberg and Smith is $001010 \frac{1}{2}00$. Further, Ygberg found that the only possible space groups were D_{2h}^5 -Pnma or D_{2h}^{16} -Pnma, the latter of which was considered to be the more plausible. Later, Smith established the space group as D_{2h}^{16} -Pnma.

Table 1. *The unit cell dimensions of barylite. Space group $Pn2_1a$. $Z = 4$. By Abrashev and Belov (1962)*

Locality	a_0	b_0	c_0	Author
Långban, Sweden	9.79 Å	11.61 Å	4.63 Å	YGBERG (1941)
Franklin, N.J. USA	9.80 Å	11.65 Å	4.71 Å	SMITH (1956)
Urals, (?) USSR	9.80 Å	11.65 Å	4.63 Å	ABRASHEV and BELOV (1962)

Recently, ABRASHEV and BELOV (1962) re-examined the structure of barylite. They established the space group as $Pn2_1a$. Consequently barylite belongs to the rhombic pyramidal class. The results of the unit cell determinations are given in Table 1.

The optical and physical properties of the Lågen Valley barylite

The barylite occurs in druses in analcite, as a rule as very thin needle-like plates up to 5 mm long, lining the walls of the vugs in a radial pattern.

The crystals are flattened parallel to $\{100\}$ and elongated in the c -direction.

They contain numerous inclusions, some of which are cubes; others are more rod-like. Fig. 2 shows one of these cubes very clearly.

The refractive indices, measured in immersion slides, using sodium light, are $N_x = 1.693 \pm 0.004$, $N_y = 1.700 \pm 0.004$. N_z was not obtained on account of the pronounced orientation of the grains parallel to the perfect cleavage $\{100\}$. N_z calculated is 1.704. The barylite from the Lågen Valley is biaxial negative, $2V(-) = 76^\circ \pm 3^\circ$. The axial angle was measured on the universal stage by cand. real. I. Bryhni.

The axial plane is parallel to $\{001\}$. The obtuse bisectrix is normal to $\{100\}$. The optic orientation is then as follows: $a = Z$, $b = X$, and $c = Y$. No dispersion of the optical axes was observed.

In contrast to the barylite from Långban and Franklin, the barylites from Norway do not fluoresce in ultra-violet light.

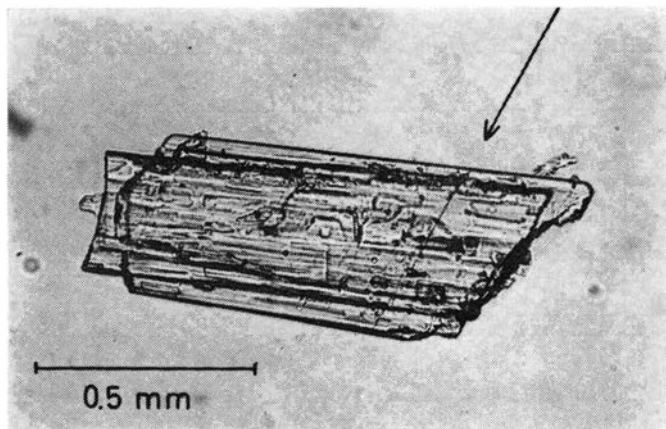


Fig. 2. Crystal-fragment of barylite laying on (100). The trace of the cleavage (011), marked with an arrow, is easily visible. One cube-like inclusion in the central part of the crystal is clearly seen.

The hardness and the specific gravity have not been determined on account of the very small amount of material at hand. The optical properties of the Lågen Valley barylite are in general agreement with those of the earlier described barylites. Table 2 gives optical and some physical properties of the five barylites hitherto described. As can be seen, some discrepancies exist that need comment.

The variations in the refractive indices are rather insignificant, but the variations in the birefringence are large, too large for a well-defined mineral like barylite with such a remarkably constant chemical composition, according to the chemical analyses published by AMINOFF (1923), PALACHE and BAUER (1930), and ZHABIN and KAZAKOVA (1960). The extremely low birefringence of the barylite from Ural may depend upon the possibility that the reported $N_z = 1.695$ has been accidentally interchanged with N_y . This is very probable when we are considering the great difficulties encountered when measuring N_z in immersion slides, on account of the perfect cleavage $\{100\}$ normal to Z , also reported for the Russian mineral. Consequently, if the reported indices are in fact N_x and N_y the birefringence of the Russian barylite becomes quite normal, max. 0.009. The unusually high birefringence of the Canadian barylite is very difficult to explain.

Table 2. *Some optical and physical properties of barylites*

Locality	Långban Sweden	Franklin N.J. USA	Urals USSR	Seal Lake Labrador	Lågen Valley Norway
Authors	AMINOFF (1923) Disp. by WEIBULL (1900)	Berman in PALACHE and BAUER (1930)	ZHABIN and KAZAKOVA (1960)	HEINRICH and DEAN (1962)	SÆBØ (This work) (2V by Bryhni)
N_x	1.6911	1.695	1.690	1.680	1.693
N_y	1.6957	1.702	—	—	1.700
N_z	1.7028	1.708	1.695	1.706	1.704 (calculated)
2V	80°54'	70° ± 2°	Medium	60°	76° ± 3°
Opt. sign...	+	—	—	+	—
Disp.	r > v weak	Not reported	Not reported	r > v moderate	Not observed
B.refr.	0.0117	0.013	0.005	0.026	0.011
H.ness	7	7	7	N.det.	N.det.
Spec.g.....	4.027	4.066	4.02	N.det.	N.det.
Fluoresc. Short w.	Blue Strong	Vivid blue Strong	Not reported	Non- fluorescent	Non- fluorescent

Barylite shows several more or less perfect cleavages. WEIBULL (1900) gave the following cleavage planes: {100} very good, {001}, {010}, and {210} less perfect, for the Långban mineral. AMINOFF (1923) did not observe the cleavage {001}, but confirmed the presence of the others reported by Weibull. In addition, Aminoff also reported an imperfect cleavage parallel to {011}. Berman in PALACHE and BAUER (1930) reported two cleavages parallel to {100} and {001} in the barylite from Franklin, N.J. Palache and Bauer further state that Aminoff reports only one cleavage. This is not the case, and the statement of Palache and Bauer is probably the result of some error in the translation from the Swedish text into English. ZHABIN and KAZAKOVA (1960) report the cleavages {100} and {000} (a misprint for {001}) in the Russian

Table 3. *Summary of reported cleavages*

No.	Locality	Cleavages	Authors
1	Långban, Sweden	Perfect {100} $\bar{1}$ Good {210}, {010}, and {001}	WEIBULL (1900)
2	Långban, Sweden	Perfect {100} Good {210} and {010} Imperfect {011}	AMINOFF (1923)
3	Franklin, N.J., USA	Good {100} and {001}	Berman in PALACHE and BAUER (1930)
4	Urals, USSR	Good {100} and {000} {000} Misprint for {001}?	ZHABIN and KAZAKOVA (1960)
5	Seal Lake, Labrador	Perfect {100} Less perfect {001}	HEINRICH and DEANE (1962)
6	Lågen Valley, Norway	Perfect {100} and {011} Good {210} Imperfect {010} and {001}	SÆBØ (This work)

mineral. HEINRICH and DEANE (1962) report two cleavages, one perfect, another good at right angles to the first. The perfect cleavage is probably {100} and the other {001}.

The barylite from the Lågen Valley shows perfect {100} and good {210} cleavages. The {010} and {001} cleavages are very imperfectly present, often completely lacking in most of the crystals examined. The {011} cleavage reported by Aminoff, on the other hand, is present and even rather perfect. The cleavage was identified in the microscope by the angle between the zone axis [c] and the trace of the cleavage on {100}. The theoretical angle x is expressed by $\text{tg } x = \frac{b_0}{c_0} = 2.505$, (unit cell values by YGBERG 1941), $x = 68.2^\circ$. The angle x measured in the microscope is 67.5° . The {011} cleavage is clearly observed in Fig. 2.

Table 3 gives a summary of the reported cleavages of the hitherto described barylites.

Spectrochemical determinations of the Lågen Valley barylite

A few mg of very pure crystal-fragments of barylite were used for one optical spectrogram. The main elements are Be, Ba, and Si. Ca is present in the order of 0.x%. The determinations were performed by Professor I. Oftedal.

The genesis of barylite

The investigations of GOLDSCHMIDT (1954) and several other geochemists on Be have made it quite clear that Be is concentrated in the later steps of the sequence of magmatic evolution. This is well demonstrated in the alkaline rock complex of the Larvik and Lange-sundfjord area. The pegmatites are the very last derivatives of the differentiation process of the kjelsåsité-larvikite-lardalite sequence. The dikes are rather rich in primary and secondary Be-minerals.

During the late tectonic movements in the Bratthagen nepheline-syenite, hydrothermal rest-solutions of magmatic origin acted upon the solid minerals of the pegmatites. The feldspars and nepheline became zeolitized and other minerals like leucophanite became strongly corroded. Elements like Na, K, Ca, Al, Ba, Be, Si, and others went into solution. These elements, together with the elements of the solution itself, readily began to deposit a distinct sequence of hydrothermal minerals at favourable places in the drusy pegmatites.

The precipitation of minerals like analcite, catapleiite, fluorite, and muscovite took away large amounts of K, Na, Al, Si, Zr, and F. After this process had ceased, the solutions still contained some Al, Be, Ba, Ca, Na, Nb, Si, P, and F. Locally and very rarely, barylite and apatite formed almost simultaneously, and, finally, as one of the very last minerals, an unknown member of the datolite group was formed. This mineral will be treated more closely later if sufficient material can be assembled. It is most probably closely related to the unnamed mineral B reported by SEMENOV, DUSMATOVA and SAMSONOVA (1963) from syenite pegmatites from Alaisk Ridge, Tadzhikistan, USSR.

The formation of this barylite is a typical example of mineral-formation in a micro-chemical fluid system. Such systems are widespread in nature in connection with the cooling of igneous rocks and are also often

connected with more deep-seated metamorphic processes. These systems are responsible for the fact that elements like Be, B, and RE elements are found in separate minerals, even if their total amounts in the systems are completely negligible. This fact is important when discussing the geological and geochemical significance of trace-elements in many metasomatic, metamorphic, and igneous rocks.

The paragenesis of barylite

The mineralogical composition of the barylite-bearing specimen is very complex. The great number of minerals clearly reflects a long period of crystallization and consequently a sequence of minerals separated into suites of more or less contemporaneous formation, each one more or less clearly separated from the preceding suite. It is immediately evident that no general physico-chemical equilibrium exists within these pegmatites. This fact explains the observed existence of the great number of minerals within one and the same specimen.

The bulk mineralogical composition is albite and analcite, together with aegirite, catapleiite, and genthelvite. There are important amounts of monazite, pyrophanite, astrophyllite, fluorite, ramsayite, and muscovite, as well as small amounts of apatite, barylite, an unidentified Be-member of the datolite group, and natrolite, together with small amounts of yellow pyrochlore, an unidentified fibrous white silicate, extremely small amounts of ilmenite, and sky-blue titanite.

We may group this number of varied minerals into two classes: the primary or magmatic minerals, which crystallized before the fracturing of the dikes, and the secondary or hydrothermal minerals, which crystallized after this period of tectonic movements. The primary minerals are aegirite, albite, glassy analcite, large amounts of catapleiite, pyrophanite, ramsayite, apatite, monazite, muscovite, fluorite, genthelvite, astrophyllite, blue titanite, and ilmenite. The secondary hydrothermal minerals are large amounts of white analcite, catapleiite and minor natrolite, small amounts of barylite, blue and white apatite, pyrochlore, fluorite, blue and grey muscovite, the Be-mineral of the datolite group, and the unidentified fibrous silicate. The barylite suite proper is barylite, apatite, and the unidentified member of the datolite group.

Concluding remarks

Barylite is an extremely rare mineral. As a rule, it occurs in very small amounts. The Seal Lake deposits represent by far the most important concentrations of barylite hitherto found. These deposits are probably of technical and economic importance.

The barylite associations show some general mineralogical and genetic features.

The Långban and Franklin parageneses are closely related. Both are formed as a result of the action of granitic and granite pegmatitic emanations on calcareous and dolomitic rocks. The deposits are briefly characterized as contact pneumatolytic and hydrothermal metasomatic skarn deposits.

The other deposits, Urals, Seal Lake, and the Norwegian mineralizations, show some general relationship. They are all of very late, hydrothermal origin, genetically related to the differentiation and cooling of intrusive alkaline and per-alkaline rock series.

Acknowledgements

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